Arctic Mixed-Phase Cloud Dissipation and its Relationship to Low CCN Concentrations

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Overview

Main Question: Can a lack of environmental CCN/aerosol be a primary factor for Arctic cloud dissipation?

- Persistent mixed-phase boundary layer clouds are important regulators for Arctic (and global) climate.
- Accurately modeling Arctic clouds are important to properly simulate the global climate system.
- Unlike in lower latitudes, Arctic aerosol concentrations have been hypothesized to be low enough to inhibit cloud formation
  - Mauritsen et al. (2011) coined the term 'tenuous clouds' in which cloud structure was limited by aerosol concentration

Cases

Two potential cases (Fig. 1) have been identified where cloud dissipation occurred coincidentally with a surface aerosol concentration decrease:

- Oliktok Point - May 12th, 2017 - Northern slope of Alaska - ocean/land boundary
- ASCOS - August 31st, 2008 - Arctic ocean ice floe

Model Description

Regional Atmospheric Modeling System (RAMS) in LES mode.

- Harrington 2-stream radiation
- RAMS 2M bulk microphysics
- dx, dy = 62.5 m
- dz = 6.25 m
- Domain = 6 x 6 x 1.25 km
- Cyclic boundary conditions

Case Observations

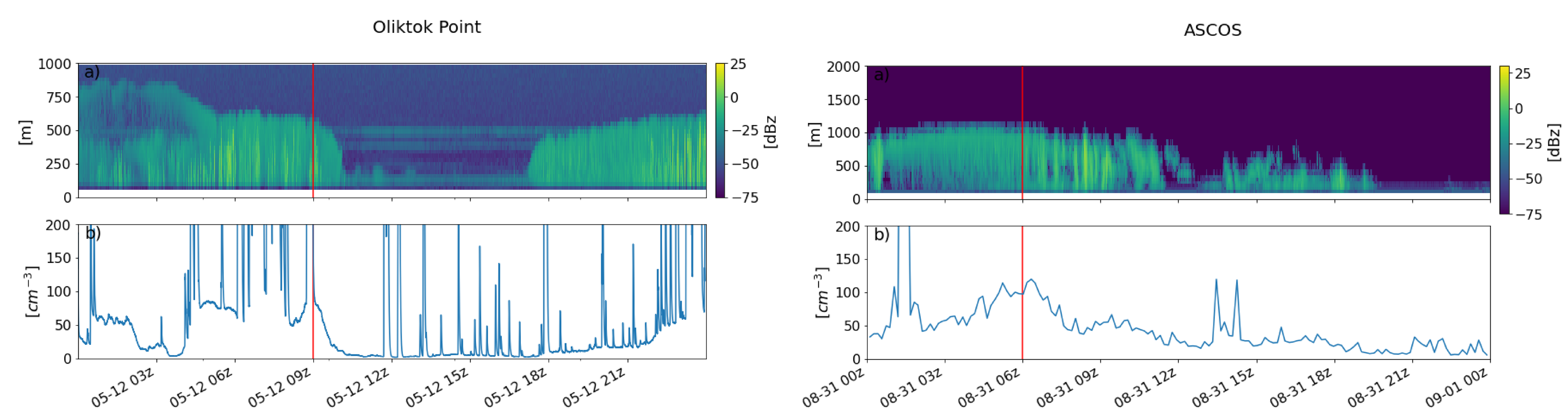

Figure 1: Observed Ka-band radar reflectivity (top) and CPC aerosol concentration (bottom) for Oliktok Point and ASCOS

Simulation Results

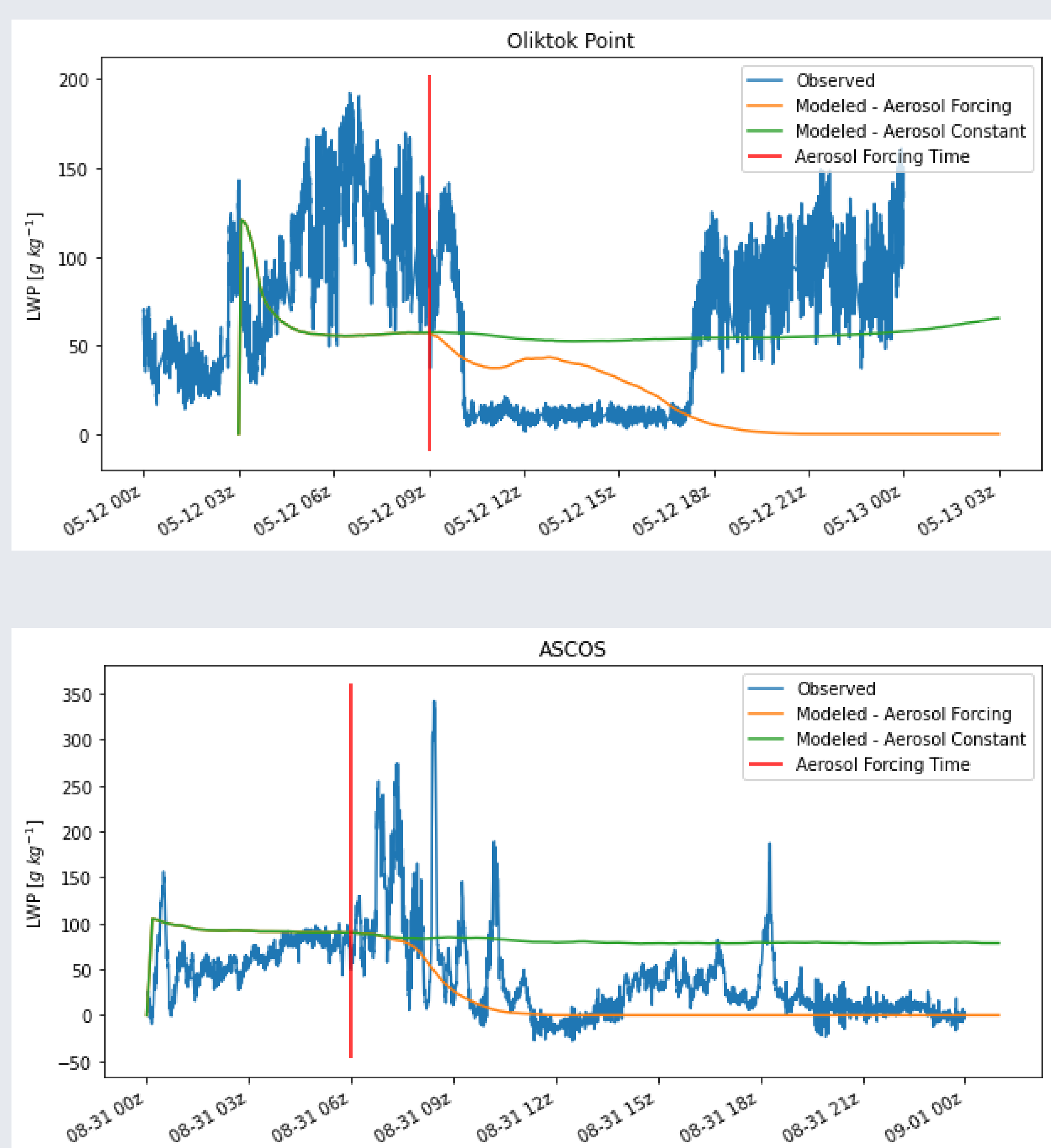

Figure 2: Observed and simulated liquid water path (LWP) for Oliktok Point (top) and ASCOS (bottom).

Balloon soundings (Fig. 3) and observed aerosol concentrations used to initialize LES model

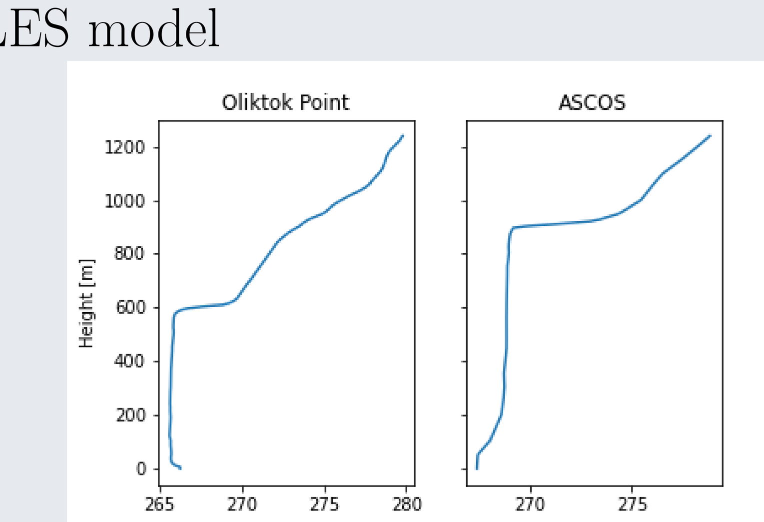

Figure 3: Boundary layer θ profiles used to initialize LES simulations

Two simulations per case:

- Stable-cloud control
  - Aerosol concentration held constant throughout, no source/sink
- Aerosol Forcing Experiment
  - Same as control, but aerosol forced to 0 cm^{-3} at the time denoted by the red line

Compare LWP response to aerosol forcing against observed LWP at time of cloud dissipation.

- Oliktok Point simulated LWP response was much slower than observed
- ASCOS simulated LWP response was similar to observed

Discussion

The extreme forcing simulations were done to ascertain whether or not aerosol-limited dissipation could be the cause of the observed dissipation cases. These extreme forcing simulations should represent the fastest possible dissipation under a "tenuous" regime.

- If the modeled LWP response was slower than the observed, then other effects must be enhancing the dissipation rate
- If modeled LWP response was faster than observed, limited aerosol may be the primary cause of dissipation, but is not possible to say for certain

Main Takeaways

- The Oliktok Point simulated LWP response was much slower than observed, indicating that other factors were likely forcing the cloud disspiation
- The ASCOS simulated LWP response matched closely with the observed decay, suggesting that the ASCOS case may have dissipated due to lack of aerosol

Conclusions

- It is difficult to isolate the role of aerosol concentration on observed cloud dissipation
- When doing an 'extreme' level of aerosol forcing, the ASCOS simulation agreed much closer to observations than Oliktok Point.
  - ASCOS dissipation may be forced by aerosol concentrations, but impossible to say for sure

Future Work

- Simulate various (and more realistic) aerosol treatment methods
- Examine in-cloud processes
- Locate and test more cases

This work was supported by US Department of Energy Atmospheric System Research Grant #DE-SC0019073-01